Direct FIR/submm detector developments for Herschel and beyond

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The Herschel Space Observatory, covering the 60 to 600 micron band for both, photometry and medium-resolution spectroscopy, has triggered several lines of direct detector development to give optimum performance over a large range in wavelength and background as dictated by the scientific performance requirements and the different instrument implementations.

The PACS instrument for the 60 to 200 micron range employs photoconductor arrays in its imaging grating spectrometer and silicon bolometer arrays in its 3-band photometer. The two 16x25 pixel photoconductor detector arrays are based on individual Ge:Ga detectors contained in integrating cavities which are fed by an array of light cones to provide for area-filling light collection in the focal plane. In order to detect light at wavelengths $>$120 microns, uniaxial stress has to be applied to each detector crystal. We have developed a method to efficiently stress an entire stack of detector elements which allows us to form two-dimensional arrays from an arbitrary number of linear detector modules. Each linear module is read out by a cryogenic readout electronics circuit integrated into the module. These circuits provide continuous signal integration by a CTIA stage for each pixel followed by a multiplexer. We have measured effective quantum efficiencies of the detector/read-out chain of $>$30% under representative background conditions, or NEPs down into the 10ˆ-18 W/sqrt(Hz) range. The PACS photometer focal plane of the short wavelength channel (60-85/85-130 mircron) is made of a mosaic of 2x4 3-sides buttable bolometer arrays (16x16 pixels each) for a total of 2048 pixels, while the long wavelength channel (130-210 micron) has a mosaic of 2 of the same bolometer arrays for a total of 512 pixels. They represent the first filled arrays (FLambda/2 size pixels) of fully collectively built bolometers with a cold multiplexed readout, allowing for a properly sampled coverage of the full instrument field of view. They have been optimised for both, high FIR absorption efficiency and minimum cross section to cosmic rays for operation in a space environment. The bolometers, working at a temperature of 300mK, have an NEP close to the BLIP limit of ˜10ˆ-16 W/sqrt(Hz) and a post-detection bandwidth of 4 to 5 Hz. The multiplexing readout, operating at the detector temperature, is hybridised to the detection layer by indium bump bonds.

The detectors in the SPIRE instrument are spider-web bolometers using neutrontransmutation-doped germanium thermometers, which are coupled to the telescope by hexagonally close-packed 2FLambda-diameter single-mode conical feedhorns, The three photometer arrays contain 43 (520 micron), 88 (360 micron) and 139 (250 micron) detectors, and the two spectrometer arrays have 19 detectors for the 325-670 micron band and 37 for the overlapping 250 - 325 micron band. The bolometers are operated at 0.3 K, which is sufficient to achieve photon noise limited performance under the Herschel telescope background. Silicon nitride micromesh absorbers minimise the suspended mass and heat capacity. The thermistor crystals are attached to absorbers with indium bump bonds. Vapour-deposited electrical leads to the thermistors determine the thermal conductance to the heat sink. The feedhorn/detector cavity optical efficiencies are typically ˜ 0.7, and the detectors achieve near-theoretical noise performance. The operating temperature of 0.3 K for the bolometric detectors in both instruments is provided by two 3He sorption coolers developed for Herschel.

The knowledge gained in the construction and characterisation of these detectors provides a strong basis for the ongoing development of concepts for future FIR/submm space missione, like SPICA, SAFIR, or FIRM, with greatly improved sensitivity and resolution.